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BIOLOGICAL EVALUATION OF WESTERN SPRUCE BUDWORM AND DOUGLAS-FIR TUSSOCK MOTH IN PROPOSED 1992 ANALYSIS UNITS

DESCHUTES NATIONAL FOREST
SISTERS RANGER DISTRICT

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INTRODUCTION

The Sisters RD on the Deschutes NF continues to experience defoliation of its mixed conifer stands by the western spruce budworm (Choristoneura occidentalis). In addition, high numbers of Douglas-fir tussock moths (Orgyia pseudostugata) have been caught in some early-warning pheromone traps on the District. These events have prompted an analysis on the District to determine the population numbers of both defoliators and to assess past and future damage levels to the District's resources. Three analysis units have been delineated on the Sisters RD and extensive field sampling has been carried out during the summer of 1991.

The purpose of this report is to summarize the results from surveys to assess defoliator populations and their impacts at the forest stand level. In addition, recommendations are made for the management of these insects.

BACKGROUND

The western spruce budworm (WSB) and Douglas-fir tussock moth (DFTM) are native insects associated with mixed conifer forests throughout the western United States. Both insects periodically reach outbreak status and can defoliate vast acreages of their host type. The cycles of DFTM outbreaks appear to be somewhat more regular than those of the WSB, occurring approximately at 9-year intervals (Mason and Luck, 1978). These outbreaks characteristically explode and then collapse very dramatically over a two- to four-year period (Fellin, 1985). Spruce budworm outbreaks can be more prolonged and populations will show resurgence whenever climatic and stand conditions permit (Fellin and Dewey, 1982).

INSECT BIOLOGY AND EFFECTS

Life cycles of WSB and DFTM:

Both insects have a one-year life cycle with the destructive larval stage occurring during the spring and early summer. The larvae molt several times (4-6) as they feed throughout the growing season of their host trees. The spruce budworm overwinters as a first-instar larva and begins feeding in May when it mines older needles and buds. Once the buds have flushed, the larvae spin loose webs around the fresh foliage and continue to feed as the shoots develop (Fellin and Dewey, 1982). The tussock moth larvae hatch from their egg masses in late May or early June, coinciding with the flush of new growth of their hosts (Wickman et al., 1981). These newly hatched larvae begin feeding on the new foliage, which they require early in their development. Later instars of DFTM are able to complete their development on older needles (Wickman et al., 1981). Both insects pupate in the summer and fall, with the budworm pupating in early to mid-July, and the tussock moth spinning its cocoons in late July and August. Adult moths hatch out shortly thereafter, and lay their eggs on other host trees. The spruce budworm female lays some eggs near the emergence site and then disperses to lay the remainder of the eggs (Fellin and Dewey, 1982). Since the tussock moth female is flightless, she

lays her eggs on the same pupal case (cocoon) from which she emerged. Budworm eggs hatch in the fall and early-instar larvae overwinter in small silken shelters called hibernacula.

Tree effects:

The primary hosts of both defoliators are Douglas-fir (Pseudotsuga menziesii), white fir (Abies concolor), and grand fir (A. grandis), with the specific preferences varying somewhat throughout the range of the insects. In southcentral Oregon, all three hosts are equally acceptable for DFTM (Wickman et al., 1981) and the true firs may be slightly preferred over Douglas-fir by WSB. In the larval stage, both insects consume the needles of their host trees. The spruce budworm prefers new foliage but will feed on older needles if new foliage has been consumed. The Douglas-fir tussock moth requires new needles early in its development, but can feed on older needles as the larvae near maturity. Budworm feeding can cause radial growth loss, top-kill, and even tree death if sustained defoliation occurs for several years. Feeding by the tussock moth can kill trees within one year in extreme cases. In addition to these direct effects, defoliated trees become more susceptible to lethal attacks by bark beetles.

Resource effects:

The effects of these defoliators cannot be labeled as negative or positive unless they are considered in the context of a particular resource. Area-specific management objectives must be the primary consideration in determining how and when to deal with high populations of a defoliating insect. Differential levels of feeding throughout a mixed stand will affect individual trees to differing degrees, and may dramatically alter the competitive balance within the stand. Among host trees, the smaller understory trees are usually defoliated more severely than larger trees. Non-hosts are usually not defoliated at all, and will benefit from the feeding which takes place on the neighboring host trees.

The relationship of defoliation and various resources is described very well by Willhite (1991), and some of those relationships are included in the following:

Recreation areas: The most obvious effect of defoliation in areas such as high-use campgrounds is the mere presence of the insects, which often produces an outcry from users. The spruce budworm is particularly noticeable due to its habit of dangling from threads and dropping from trees onto campground visitors. In these cases, there is usually little tolerance of high insect populations. In addition, color changes in tree crowns from green to reddish-brown in mid- and late-summer can be especially noticeable and is usually considered undesirable by recreationists. Another consequence of high defoliator populations in campgrounds would be the need to clean up hazard trees where extensive tree mortality occurs.

Old Growth: If ponderosa pine is the featured species, then the defoliation of true firs and Douglas-fir can be viewed as having an overall positive effect. These shade-tolerant trees provide heavy competition to

older overstory pines, and can dramatically increase the pines' susceptibility to western pine beetle and other agents which thrive on stressed trees. Defoliation in mixed conifer old-growth stands would have differential effects throughout the various canopy layers, and would probably affect overstory trees to a lesser degree than understory trees. Secondary attack by bark beetles on defoliated trees is often associated with severe and prolonged budworm outbreaks, but these effects are much less evident on the Sisters RD than in drier parts of the Region such as the Blue Mountain Forests.

Timber: The effects of insect defoliation on timber are understood better than the effects on most other resources. Defoliation produces short-term growth loss, top-kill, and mortality, all of which reduce timber yields. These effects are most pronounced where stand density and percent host cover are greatest.

Summer range: Heavy defoliation could affect thermal and hiding cover for big game by creating patches of mortality in dense stands.

Fire management: If mortality in stands is intensive and concentrated, the risk of fire would be greatly increased. Dead trees may remain standing for a decade or slightly more, but thereafter they would become a substantial fuel load on the ground. In such a situation, the effects of a fire on soils could be severe.

CURRENT SITUATION

As shown in Table 1, there were nearly 120,000 acres of western spruce budworm defoliation mapped on the Sisters RD in 1991. This total acreage is slightly higher than mapped in 1990, and the intensity of feeding is substantially higher than in 1988 when similar acreages were defoliated on the District. Over 7,000 acres were mapped as Code 4 defoliation. These acres contain many trees where no green is visible from the air, tops are bare, and trees are gray in color (Table 1). Some of these pockets of nearly complete defoliation are in and around recreation areas and other highly visible areas, and have caused concern on the part of visitors to the Forest. The current outbreak has persisted in the area for several years and has produced concerns about potentially high levels of tree mortality and increased fire risk. In addition, early warning pheromone trapping of tussock moths in 1990 yielded trap catches in excess of 40 moths per trap in two of five sampling areas, prompting further concern about the fate of host trees on the District.

Table 1. Acres of defoliation by the western spruce budworm by year and code class for the Sisters RD, Deschutes NF, 1985-1991.

	1985	1986	1987	1988	1989	1990	1991
Code 1	134,170	131,870	51,390	122,700	15,147	15,501	35,200
2		3,810	2,090	12,600	9,801	66,163	43,520
3				140	29,280	6,195	33,920
4					3,306		7,040
Total	134,170	135,680	53,480	135,440	57,534	87,859	119,680

Code 1 - Current defoliation visible from the air
2 - Current defoliation with some bare tops visible (very little gray); still a lot of green foliage on trees
3 - Current defoliation with a lot of bare tops visible (somewhat gray in color); some green foliage still remaining on trees
4 - Current defoliation with a lot of bare crown visible (very gray in color); no green visible on host trees

METHODS

Analysis Unit delineation:

Three analysis units were delineated on the District, based on the distribution of susceptible host type and on the indicators of high defoliator populations. These three units were subdivided into smaller units as shown in Appendix A.

Analysis hierarchy:

In order to reduce the size and complexity of the task of analyzing areas for defoliator populations, R6-FPM has developed some guidelines to be followed for WSB and DFTM assessment. The guidelines are based on threshold population levels, which, if reached, trigger the next step in the analysis. If at any point the defoliator population is not at the threshold, the analysis is discontinued. For example, DFTM analysis begins when adults caught in pheromone traps exceed 40 moths per trap. Analysis Units are then delineated and lower crown larval sampling is done in the early summer in those areas where trap catches are above the threshold. If the larval sampling produces more than two larvae per 1000 square inches of mid-crown foliage, the analysis continues with cocoon sampling in the fall. For the WSB, the first threshold of analysis is the detection of defoliation in the aerial survey. If heavy defoliation is mapped for at least one year, or moderate defoliation for at least two years, then analysis units are delineated and lower crown larval sampling is done in the summer. The threshold of larval numbers needed to continue the budworm analysis is eight larvae per sample (three 45-cm branch

tips per tree). If this threshold is reached, pheromone traps are deployed in the late summer and stand impact data are collected at the same sites where larval sampling was done.

Population assessments:

Larval sampling

Since the initial analysis thresholds were exceeded for both defoliators, lower crown sampling was done during the first ten days of July, 1991, in accordance with the lower crown beating procedure described by Mason et al., 1989. Larval sampling was timed to coincide with foliage being elongated about 1-1/2 inches, which means that newly hatched DFTM larvae have finished dispersing and WSB are in the nominal fourth instar.

Lower crown larval samples were collected from 10 host trees on each of the ten plots established within each subunit (100 total plots sampled). The plots were distributed fairly uniformly in order to represent the variation within each subunit. Plots were located along forest roads, but sample trees were selected away from the road to minimize the influence of dust. Sample trees were either true firs or Douglas-firs with branches easily accessible from the ground. Three branches were sampled from each tree and larval counts of both DFTM and WSB were totalled for each sample tree. Where budworms exceeded 50 per branch, crews indicated 50+ on the tally sheet for those branches.

Pheromone trapping

Since WSB larval counts far exceeded the threshold for continued analysis, budworm pheromone traps were deployed in mid-July. The milk carton sticky traps were placed on host trees at each of the plots used for larval sampling earlier in the month. One pheromone trap was deployed per plot. The traps were baited with PVC pellets impregnated with tetradecenal, the mating pheromone of WSB. Traps were brought in from the field in mid-August as the flight period of WSB was almost concluded. The numbers of moths were then tallied for each plot and were summarized by Analysis Subunit.

Pheromone trap catches are used to predict budworm defoliation in the subsequent year. Relationships between the moth catches and next year's larval populations have been worked out by Sartwell (USDA Forest Service, PNW Station, as cited by Bridgwater, 1991), and are as follows:

0-4	moths	per	trap	-	defoliation undetectable by cursory observation;
5-19	"	"	"	-	patchy defoliation within some areas;
20-34	"	"	"	-	most trees lightly defoliated;
35-44	"	"	"	-	stand moderately defoliated;
45-55	"	"	"	-	heavy defoliation of upper crowns;
>55	"	"	"	-	heavy defoliation of entire crowns.

DFTM pheromone trapping had been done in 1990 as part of the Region's DFTM Early Warning System, established in 1979 to provide timely information to resource managers regarding increases in tussock moth populations. Within this system, the Sisters District deploys 25 traps, five each in five locations.

Impact assessment in stands:

This portion of the analysis was designed to determine the effect that budworm feeding is having on its host trees. Defoliation, both current and accumulated, may produce some level of top-kill or tree mortality in certain stands. By assessing this impact, resource managers can better determine areas in which suppression may be beneficial, as well as finding areas where past damage has been too extensive and where little can be gained through suppression by application of insecticides. This impact assessment was done at each of the 100 plots where larval samples were taken and where pheromone traps were installed. At each trap site, a variable radius plot was established using a 20 BAF prism (relaskop). All trees greater than 3" dbh within the variable plot were measured. Information collected from each tree included the following: species, diameter at breast height, condition (alive, died during present outbreak, or died before outbreak), and crown class. For budworm host trees, the percent bare top was recorded, along with crown ratio, the amount of missing foliage (cumulative defoliation over the years), and degree of current defoliation. The missing foliage and current defoliation were rated in 10%-classes for each third of the crown, but for ease of analysis are summarized in broad categories of "light", "moderate", and "heavy" defoliation.

On each plot, an estimate was made of how long the outbreak has been evident in the area. This judgment was based on the number of years that foliage showed evidence of budworm feeding.

Data are presented in terms of basal area per acre rather than trees per acre. Some computations of trees per acre were done on a limited basis.

RESULTS AND DISCUSSION

Analysis hierarchy

For DFTM, the analysis was triggered by high pheromone trap catches in 1990 in two areas (Jack Creek and Bear Springs subunits). Larval numbers collected in 1991 were below the suboutbreak level and thus no further analysis was necessary for this defoliator.

WSB was aerially detected for the seventh consecutive year, and lower crown sampling was initiated to determine population numbers for 1991. The larval numbers exceeded the threshold of 8 larvae per tree, which prompted the continuation of the analysis with pheromone trapping and impact assessment in July and August, 1991.

Population assessments:

Larval sampling

Larval numbers for DFTM are shown in Table 2. (These numbers represent the larvae per 1000 square inches of foliage in the lower crown; in order to determine densities at midcrown, the values in Table 2 should be doubled). In all but two subunits, the tussock moth populations were well below the suboutbreak level of 2-20 larvae per 1000 square inches of foliage. Even where pheromone trap catches had exceeded 40 moths per trap (Jack Creek and Bear Springs subunits), the larval numbers did not materialize. After the numbers in Table 2 are doubled, only the Black Butte and Prairie Farm subunits show suboutbreak populations at this time. Historically, the tussock moth has not reached high levels on the Deschutes NF (R. R. Mason, PNW Research Station, LaGrande OR, personal communication) and suboutbreak populations were not expected to be found. Two prominent factors may have played a role in the low DFTM larval numbers for 1991. The major one would be the abundance of WSB larvae on the same trees colonized by DFTM. Since the budworm development is far along when DFTM larvae first disperse, there is much less fresh foliage for the late-arriving tussock moth to feed on. A second potentially important factor was a phenomenon affecting the new growth on host trees. There was extensive wilting and subsequent dessication of new host foliage in 1991. Shoot elongation was substantial, but wilting of uneaten needles occurred once the flush of new growth was complete. These limp needles dried out by the time that budworm defoliation was finished, and the extra red color contributed substantially to the overall symptoms evident throughout the District. The reasons for this foliage dessication are not known, but the symptoms resembled those resulting from frost damage. The widespread occurrence of this condition is somewhat confounding in that frost damage usually tends to be more localized.

Based on this deteriorated foliage condition, the historical absence of high tussock moth populations, and the extreme competition in 1991 from spruce budworm, the DFTM populations are expected to be low in 1992.

Table 2. Average numbers of Douglas-fir tussock moth larvae per 1000 square inches of foliage from lower crown beating plots on Sisters RD, Deschutes NF, 1991.

Analysis Unit	# Plots	Average # Larvae[1] per Sample
Green Ridge AU	**40**	**1.06 ± 1.82**
Black Butte	10	1.56 ± 3.15
Bear Springs	10	0.44 ± 0.68
Prairie Farm	10	1.36 ± 1.43
Street Creek	10	0.88 ± 0.99
Jack Creek AU	**30**	**0.66 ± 0.67**
Abbot	10	0.74 ± 0.37
Jack Creek	10	0.76 ± 1.04
Round Lake	10	0.48 ± 0.41
Santiam AU	**30**	**0.25 ± 0.29**
Santiam	10	0.16 ± 0.31
Cache	10	0.22 ± 0.32
Bluegrass	10	0.36 ± 0.21

[1]Means are followed by standard deviation of values within the subunit

Table 3 contains a summary of the WSB larvae collected by lower crown sampling. All subunits contained numbers far in excess of the 8 larvae per tree which would trigger additional sampling later in the season. The highest larval numbers were recorded in the Jack Creek Analysis Unit where the heaviest defoliation was mapped for 1991 during the aerial survey. (In order to convert these numbers to larval numbers per 18-inch branch tip at midcrown, the numbers in Table 3 need to be multiplied by a correction factor of .75).

Table 3. Average numbers of western spruce budworm larvae per tree from lower crown beating on Sisters RD, Deschutes NF, 1991.

Analysis Unit	# Plots	Average # Larvae per Tree
Green Ridge AU	**40**	**27.5 ± 14.1**
Black Butte	10	23.3 ± 16.8
Bear Springs	10	39.0 ± 2.9
Prairie Farm	10	32.6 ± 11.4
Street Creek	10	15.2 ± 8.9
Jack Creek AU	**30**	**47.3 ± 15.0**
Abbot	10	51.7 ± 13.0
Jack Creek	10	49.1 ± 14.2
Round Lake	10	41.1 ± 16.8
Santiam AU	**30**	**34.0 ± 13.4**
Santiam	10	29.3 ± 18.0
Cache	10	32.3 ± 11.7
Bluegrass	10	40.5 ± 6.5

Pheromone trapping

Trap catches for WSB adults are shown in Table 4. The numbers of moths trapped were quite high in all of the Analysis Units, ranging from nearly 46 per trap in the Green Ridge Unit to 55 in the Santiam Unit. Using Charlie Sartwell's criteria developed at PNW (Bridgwater 1991), these trap catches predict moderate to heavy budworm defoliation throughout the area again in 1992.

Table 4. Average numbers of western spruce budworm adults per pheromone trap on Sisters RD, Deschutes NF, 1991.

Analysis Unit	# Traps	Adults per Trap	Predicted 1992 Defoliation
Green Ridge AU	**38**	**45.7 ± 12.59**	**M to H**
Black Butte	9	43.4 ± 14.70	Moderate
Bear Springs	9	50.9 ± 9.35	Heavy
Prairie Farm	10	43.2 ± 10.04	Moderate
Street Creek	10	48.6 ± 5.9	Heavy
Jack Creek AU	**29**	**47.4 ± 13.07**	**Heavy**
Abbot	10	48.4 ± 9.98	Heavy
Jack Creek	10	45.7 ± 15.0	M to H
Round Lake	9	48.2 ± 15.08	Heavy
Santiam AU	**30**	**55.0 ± 18.16**	**Heavy**
Santiam	10	59.5 ± 25.27	Heavy
Cache	10	52.9 ± 13.27	Heavy
Bluegrass	10	52.6 ± 14.63	Heavy

Impact assessment in stands:

The condition of defoliated host trees is summarized in Table 5. The most notable feature in this table is that tree mortality has been very low, despite several years of defoliation. **(NOTE: It is important to point out that the small-diameter trees are strongly under-represented in variable radius plots. Budworm-caused mortality tends to be much higher in smaller trees, and as a result, these data will understate total tree mortality for the areas. Another important consideration is that larval sampling required trees with live lower crown foliage, and areas with heavy mortality may have been avoided when plots were established.)** No tree mortality was noted in the 40 plots within the Green Ridge AU. In the Jack Creek AU, 5% of the basal area died during the current outbreak, while 6% of the basal area was dead in the Santiam AU. The dead trees on the plots were mostly white firs, ranging in diameter from from 6.7" to 19.1" dbh; some Douglas-firs (10.1" to 20.2" dbh) and subalpine firs (15.6" to 18.2") were also among the trees that died during this budworm outbreak. The percentage of green trees (defined as trees without bare tops) was highest in the Green Ridge AU, where budworm populations have built up more recently than in other parts of the District. Within the other two Analysis Units, about one-sixth of the basal area had bare tops greater than 25% of the total height of the trees (Table 5). Trees in this condition are likely to exhibit top-kill if budworm defoliation continues in the area. The Jack Creek

Table 5. Percent basal area per acre with bare tops within stands defoliated by the western spruce budworm on Sisters RD, Deschutes NF, 1991.

			T R E E C O N D I T I O N				
			1-10%	11-25%	>25%	Dead During	Dead Before
Analysis Unit	# Trees	Green	Bare Top	Bare Top	Bare Top	WSB Outbreak	WSB Outbreak
Green Ridge AU	210	88	8	3	1	0	0
Black Butte	54	74	19	6	6	0	0
Bear Springs	48	81	10	8	0	0	0
Prairie Farm	57	98	2	0	0	0	0
Street Creek	51	96	4	0	0	0	0
Jack Creek AU	175	22	43	14	14	5	2
Abbot	61	28	52	7	5	3	5
Jack Creek	58	7	48	10	21	3	0
Round Lake	56	21	25	27	18	9	0
Santiam AU	178	31	34	15	15	6	0
Santiam	66	33	21	17	21	8	0
Cache	55	53	24	18	2	4	0
Bluegrass	58	7	57	9	19	7	0

NOTE: For purposes of comparison, the percent of dead trees per acre were computed for the three most heavily affected subunits (Round Lake, Santiam, and Bluegrass). In Round Lake, the 9% BA which died during the outbreak converts to 7% of the trees per acre; for Santiam, 5% of the trees per acre are dead; for Bluegrass, 7% TPA dead during current WSB outbreak.

and Santiam AU's each also had another sixth of the basal area with 10-25% bare-topped trees.

The percent of cumulative defoliation (missing foliage) is shown in Table 6. This is the result of the severity of defoliation and the number of years in which defoliation has occurred. In the Green Ridge AU, trees representing only 24% of the basal area showed heavy cumulative defoliation, while 90% and 95% of the basal area in the other two Units was heavily defoliated.

Table 6. Percent basal area per acre with various degrees of missing foliage (total cumulative defoliation) on Sisters RD, Deschutes NF, 1991.

Analysis Unit	# Trees	None (Green)	Light (0-25%)	Moderate (26-50%)	Heavy (>50%)
Green Ridge AU	**210**	**20**	**37**	**19**	**24**
Black Butte	54	13	37	30	20
Bear Springs	48	0	37	15	48
Prairie Farm	57	26	41	12	21
Street Creek	51	39	33	18	10
Jack Creek AU	**163**	**1**	**4**	**0**	**95**
Abbot	57	0	0	0	100
Jack Creek	54	0	0	0	100
Round Lake	52	2	12	0	86
Santiam AU	**167**	**2**	**0**	**8**	**90**
Santiam	60	7	0	15	78
Cache	54	0	0	7	93
Bluegrass	53	0	0	0	100

Table 7 contains the data on current defoliation. The numbers are extremely high in all units due in part to budworm defoliation, but also to extensive wilting and dessication of uneaten needles. It was not possible for field crews to distinguish between these two factors affecting the new growth, and they were instructed to record the total percent of new foliage which was no longer available to the tree. Since uneaten 1991 needles will not be useful in the coming years, the host trees may be somewhat more vulnerable to additional defoliation in the future.

Table 7. Percent of basal area per acre with various levels of missing needles from the current year (Sisters RD, Deschutes NF, 1991).

Analysis Unit	# Trees	Percent Current Defoliation[1] None	Light	Moderate	Heavy
Green Ridge AU	**212**	**1**	**9**	**8**	**82**
Black Butte	55	0	7	11	82
Bear Springs	48	0	2	6	92
Prairie Farm	58	0	9	7	84
Street Creek	51	6	20	6	69
Jack Creek AU	**161**	**0**	**0**	**2**	**98**
Abbot	57	0	0	0	100
Jack Creek	52	0	0	0	100
Round Lake	52	0	0	6	94
Santiam AU	**166**	**0**	**0**	**1**	**99**
Santiam	58	0	0	0	100
Cache	55	0	0	2	98
Bluegrass	53	0	0	0	100

[1]This figure includes defoliation by both the western spruce budworm and by other unknown factors which caused wilting and dessication of uneaten needles

RECOMMENDATIONS

A discussion of recommendations must be prefaced by a summary of the predictive information and impact data which have been collected and analyzed. There are some clear indicators that spruce budworm populations can be expected to be high once again in 1992. High larval numbers occurred throughout all of the Analysis Units in 1991, and budworm survival was apparently good, as indicated by high numbers of moths caught in pheromone traps. Even though populations were in outbreak status this year, and have been that way for at least three years in most of the area, the impacts on the resource have not been as pronounced as they appear on the surface. Tree mortality has not been high thus far within the analysis units. The potential for top-kill is increasing, but top-kill has also not been high to date. These impact numbers suggest that the District can afford to wait another year before taking suppression action against the budworm if the insecticidal spray treatment alternative were chosen. Stand vulnerability in the coming years will be a function of precipitation patterns, and a return to higher rainfall could bring about a collapse of these populations. If feeding continues, however, there clearly will be accelerated top-kill and tree mortality since these effects begin to show up after several years of accumulated defoliation. The regional climatic differences between the foothills of the Cascades and forested areas further east suggest that there may be differences in stand susceptibility between the Sisters area and areas such as the Blue Mountains (Carlson and Wulf, 1989).

Recommendations are as follows:

1. The Sisters RD should continue to monitor the development of insect populations throughout those areas where budworm defoliation and its resultant top-kill or mortality are unacceptable for the stated management objectives. This would include refining the present Analysis Unit boundaries (if needed) to be able to exclude any area where defoliation does not interfere with the management objectives. An example of an area not requiring further monitoring would be where true firs have encroached into older ponderosa pine stands and management direction is to feature those pines. Areas where budworm-caused mortality might be considered unacceptable could include intensive recreation areas.

2. A long-term plan should be considered whereby unnaturally dense mixed conifer stands would be altered by silvicultural means to reduce their susceptibility to defoliating insects and other pests which thrive on these conditions. This plan would take many years to implement fully since there are vast acreages of susceptible stands at this time. Stand conversion to seral species (ponderosa pine and western larch where appropriate) should be a long-term goal and should begin very soon in high priority areas. Once again, management areas and management emphasis would help determine where those priority areas would be.

3. Direct suppression by application of insecticides is not recommended in any areas where WSB defoliation does not impede the attainment of stated management objectives. Pesticide application is a short-term tactic to minimize damage until other long-term measures can be employed to change stand susceptibility. In areas where such long-term management activities would not be carried out (e.g., Wilderness areas, Research Natural Areas),

pesticide application should not be done. If the direct suppression alternative is chosen for any area, then treatment unit boundaries should be very carefully defined so as to treat only those areas which contain susceptible host type. Areas as small as 50 acres of non-host should be delineated for exclusion if possible.

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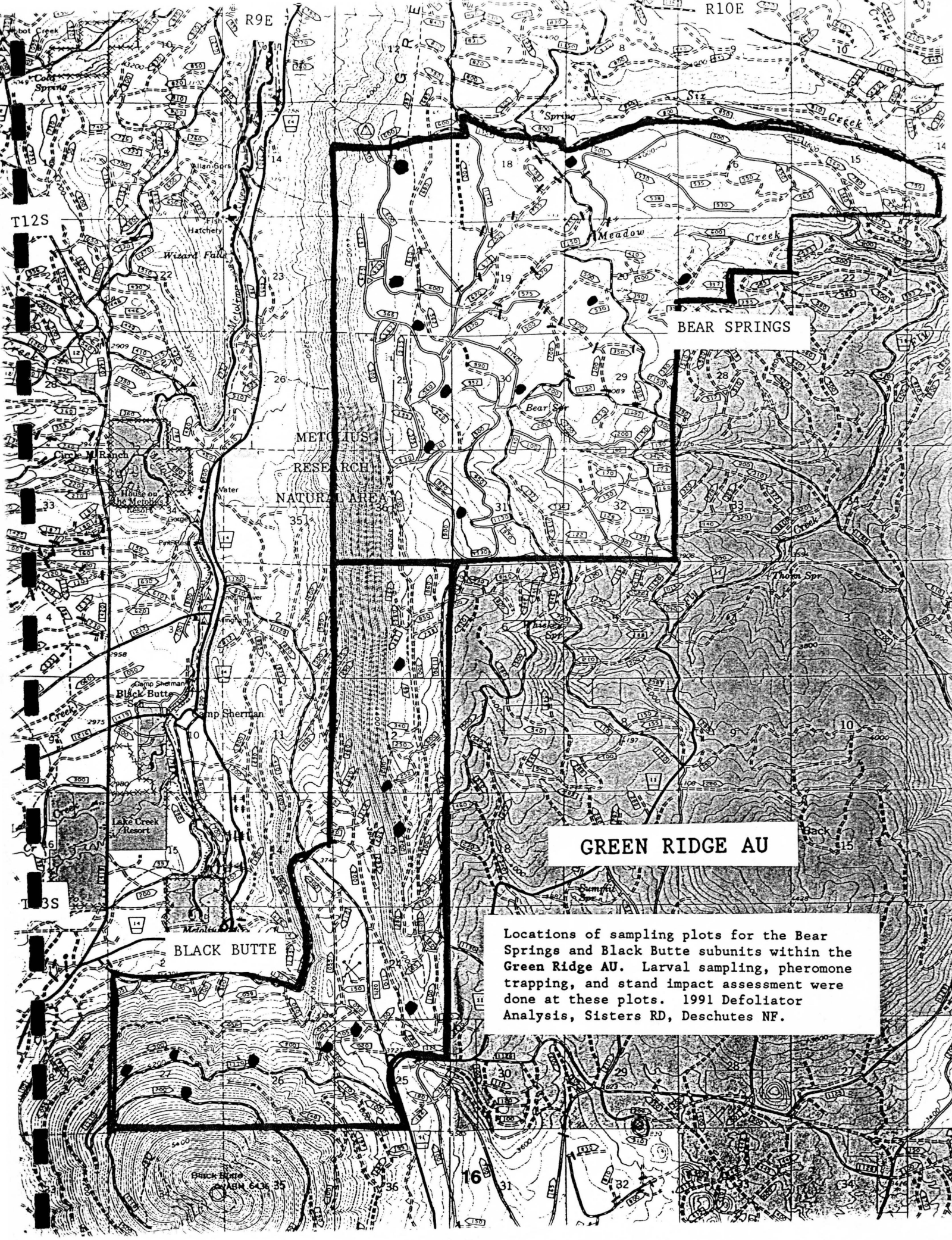
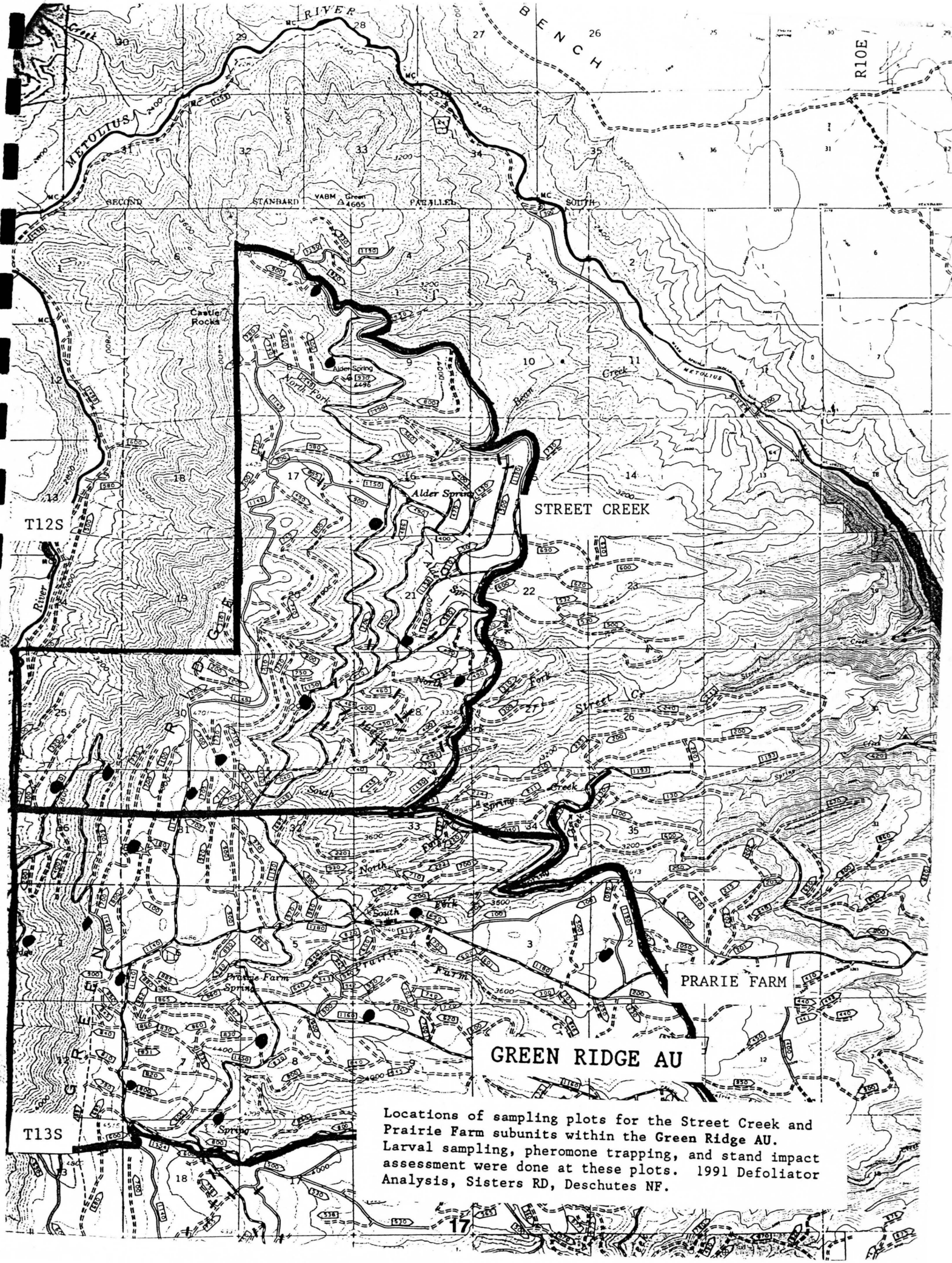
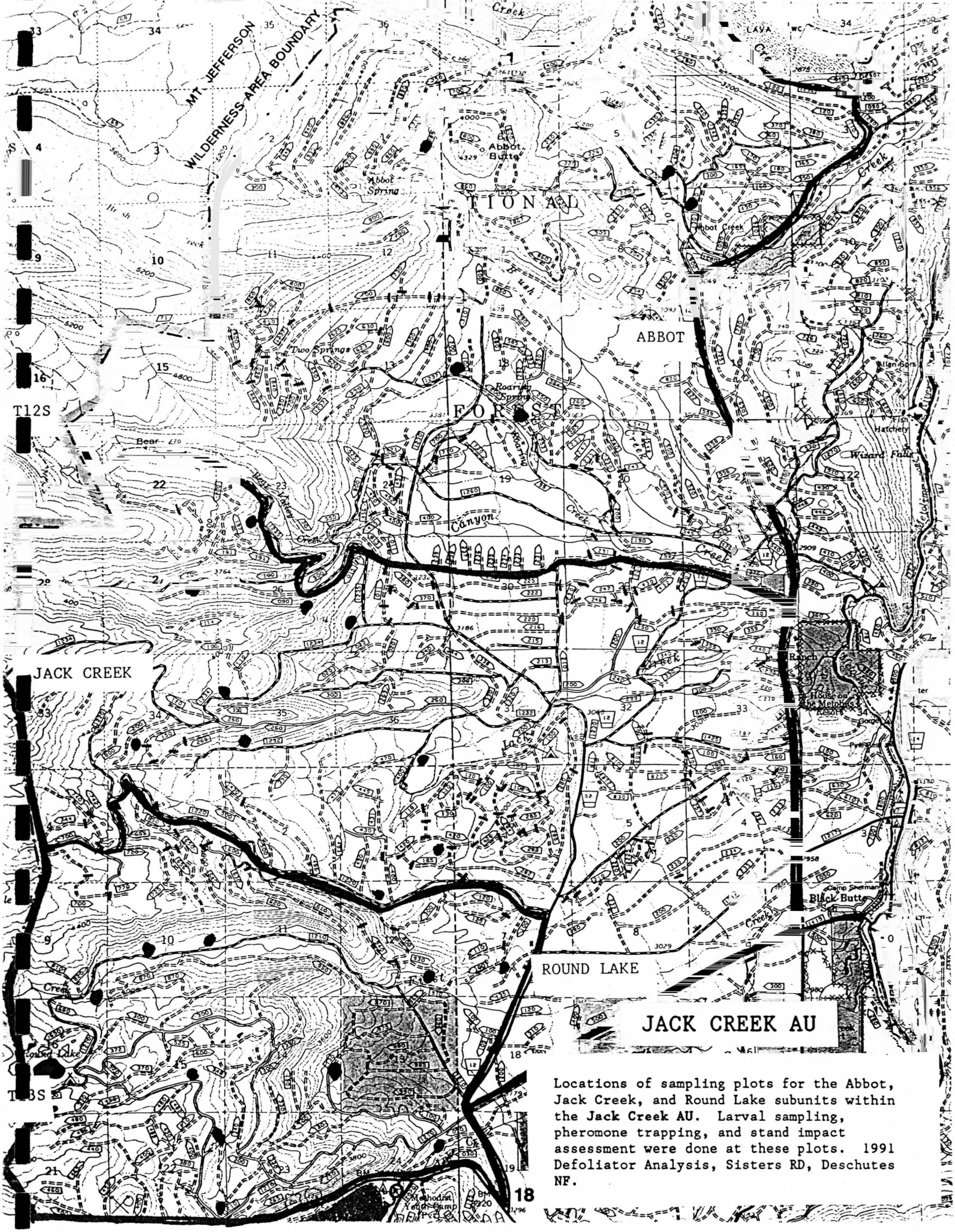


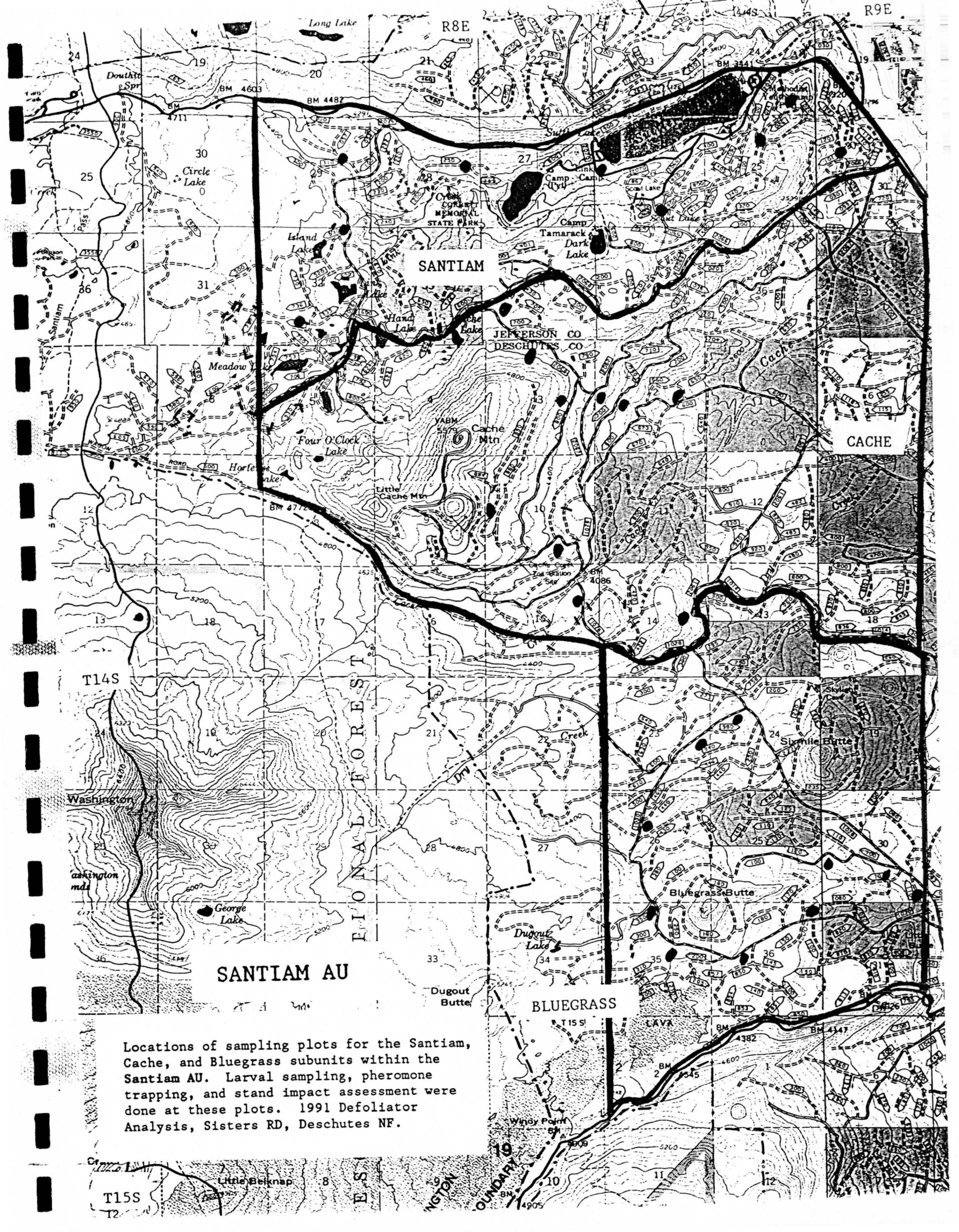
Locations of sampling plots for the Bear Springs and Black Butte subunits within the **Green Ridge AU.** Larval sampling, pheromone trapping, and stand impact assessment were done at these plots. 1991 Defoliator Analysis, Sisters RD, Deschutes NF.



Locations of sampling plots for the Street Creek and Prairie Farm subunits within the Green Ridge AU. Larval sampling, pheromone trapping, and stand impact assessment were done at these plots. 1991 Defoliator Analysis, Sisters RD, Deschutes NF.



Locations of sampling plots for the Abbot, Jack Creek, and Round Lake subunits within the **Jack Creek AU**. Larval sampling, pheromone trapping, and stand impact assessment were done at these plots. 1991 Defoliator Analysis, Sisters RD, Deschutes NF.



Locations of sampling plots for the Santiam, Cache, and Bluegrass subunits within the **Santiam AU**. Larval sampling, pheromone trapping, and stand impact assessment were done at these plots. 1991 Defoliator Analysis, Sisters RD, Deschutes NF.